ble to grain already in the ground, and that sown in September and October germinated nicely, generally came up to good stands, and maintained a slow and steady growth. At the close of the month it was everywhere reported to be in excellent condition.—*A. B. Wollaber.*

Pennsylvania.—At the close of the month the soil was in good condition in practically all sections and frozen sufficiently deep to cause a suspension of plowing; wheat and rye ranged from medium to very good, but were generally short on account of late seeding; considerable corn remained uncut; there was but little snow in any district for the protection of grain or grass.—*T. F. Townsend.*

Porto Rico.—Heavy thunderstorms and high winds on the 23d and 24th did some damage to fruits and small crops in some localities, but, in general, the weather was favorable for growing crops and for fieldwork. The older canes commenced to arrow freely in the drier sections of the island early in the month, and near the close a few mills had begun grinding. The outlook for a good yield was very promising. The young canes were in excellent condition. Coffee picking progressed rapidly during the first half of the month under very favorable weather conditions, and at the end of the month this work was nearing completion. Several small plots of cotton were picked, and where the crop had proper care the return was very satisfactory. Some rice and corn were harvested, while other plots were in the blossoming stage. Orange shipping was active. Pastures and stock continued in excellent condition.—*E. C. Thompson.*

South Carolina.—The first six days and the middle of the second decade were warm; the rest of the month was unusually cold, with killing frost on the 7th and 8th and the first ground freeze on the 18th and 19th, after which the month remained cold, with frequent frosts and ground freezes. The precipitation was light, but evenly distributed. Oats seeding was nearly finished, but germination was slow and stands small. Wheat seeding made slow progress, and but little of that sown came up to stands. Many bolls of late cotton were destroyed in the western counties by frosts and low temperatures. The crop was picked closer than usual and picking was practically finished. The cold weather injured fall and winter truck, but was favorable for butchering hogs, making a saving of nearly one month of feeding.—*J. W. Bauer.*

South Dakota.—There was considerable cold weather after the 14th, and snows interfered locally to some extent with field farm work, but the conditions were, on the whole, favorable. There was, however, considerable corn yet in the field in the Sioux River Valley at the close of the month. Thrashing was about finished. Winter rye and the very limited amount of winter wheat sown were protected by snow during the cold weather and kept in satisfactory condition.—*S. W. Glenn.*

Tennessee.—Conditions were generally favorable for gathering crops and seeding grain. Good rains fell about the first and middle of the month; otherwise it was rather dry. The second half of the month was cold. Early sown wheat was generally looking well, but much of the crop was sown late and made slow progress; the acreage is much less than last year; there was some injury by freezes. Rye and oats were doing fairly well. Spring clover was injured by the fall drought. Corn and cotton were mostly gathered.—*H. C. Bate.*

Texas.—The month was the driest November on record. Decided falls in temperature occurred on the 18th and 19th and the 27th and 28th, giving freezing temperatures to the coast region. Conditions were exceptionally favorable for the picking of cotton. About one-eight of the crop is still in the fields in the north portion, but elsewhere the crop is practically all picked. The freeze of the 18th and 19th killed the cotton plants, but, as there was little or no top crop, this caused very slight damage. Wheat, rye, and oats that were up at the beginning of the month continued in fair condition, but needed rain. The dry condition of the soil greatly retarded plowing and sowing. No damage was done to the sugar cane crop by the cold weather. Cutting and grinding progressed rapidly with very satisfactory results. Fall gardens, pastures, and the ranges were in need of rain.—*L. H. Murdoch.*

Utah.—Temperatures during the month were generally above normal, excepting during the latter part of the second decade, when abnormally cold weather prevailed. Precipitation was above normal over the northern half of the section, placing the soil in good condition and favoring rapid germination and growth of fall grain, which was coming up to good stands over the southern half, where, however, but little fall grain was sown; scarcely any precipitation fell and the ground was dry and hard. Stock and ranges were in good condition.—*R. J. Hyatt.*

Virginia.—Crop progress during the month was much retarded by weather conditions that were both colder and drier than normally. Early sown winter grain was not materially injured on account of its more advanced stage of growth, but the late seeding of wheat, oats, rye, and clover was damaged, especially on wet soils.—*Edward A. Evans.*

Washington.—The month was one of heavy rainfall in the western section and an unusual amount of rain and snow fell in eastern section. The first decade was warm, the second decade cold with heavy frost and considerable snow, while the third decade was moderately warm. On account of much stormy weather, the month was unfavorable for farm work, but it was beneficial to the growth of fall sown wheat. Late crops were mostly gathered in all districts.—*G. N. Salisbury.*

West Virginia.—The dry weather, followed by the freezing temperatures with no snow protection during the latter half of the month, was very unfavorable for the growth of winter wheat, rye, and oats, and at the close of the month they were in poor condition. The acreage of wheat sown was not as large as usual. Stock was generally in good condition and feeding began earlier than usual. Some corn was still in shock, and the prospects were for a better crop than had been expected. It was too dry for turnips.—*E. C. Vose.*

Wisconsin.—The month was generally fair and pleasant during the first ten days with temperatures above normal, but from the 12th to the end of the month, decidedly cold weather for the season prevailed. Moderately heavy rains occurred on the 11th, turning to snow. Snow occurred again on the 17th, 23d, and 28th, and ranged in depth at the end of the month from two to ten inches. Winter grains and grasses were amply protected by the snow, and were reported in good condition.—*W. M. Wilson.*

Wyoming.—Uunusually pleasant weather with mild temperatures prevailed over the State during the first and last two weeks of the month A cold wave on the 17th and 18th was general, but was not severe on stock. Practically all of the precipitation of the month fell during the stormy period from the 7th to the 17th of the month.—*W. S. Palmer.*

SPECIAL CONTRIBUTIONS.

STUDIES ON THE CIRCULATION OF THE ATMOSPHERES OF THE SUN AND OF THE EARTH.

By Prof. FRANK H. BIGELOW.

II.—SYNCHRONISM OF THE VARIATIONS OF THE SOLAR PROMINENCES WITH THE TERRESTRIAL BAROMETRIC PRESSURES AND THE TEMPERATURES.

SEVERAL OPINIONS ON THE SUBJECT OF SYNCHRONISM.

The numerous studies during the past fifty years into the apparent synchronism between the solar variations of energy and the terrestrial effects, as shown in the magnetic field and the meteorological elements, have been on the whole unsatisfactory, if not disappointing. Just enough simultaneous variation has been detected in the atmospheres of the sun and the earth to fascinate the attentive student, if not to justify a large expenditure of labor, in view of the great practical advantages to be obtained in the future as the result of a complete understanding of this cosmical pulsation. The attack upon the problem has really consisted in rather blindly groping for the most sensitive pulse in the entire cosmical circulation, and in disentangling the several interacting types of impulses. It is evident that the partial failures hitherto attending this work have been due to two principal causes: (1) The comparison was made between the changes in the spotted areas of the sun and the terrestrial variations, but these solar changes were not sensitive enough to register a complete account of the action of the solar output. Discussions of the spots are being replaced by others upon the solar prominences and faculæ, which respond much more exactly to the working of the sun's internal circulation. (2) The magnetic and the meteorological observations have not been handled with sufficient precision to do justice to the terrestrial side of the comparison. It is evident that all these physical data at the sun and at the earth must be computed with an exactness comparable to that of astronomical observations of position, if meteorology is to be raised to the rank of a cosmical science. When one considers the crudeness of the meteorological data, taken the world over, due to the character of the instruments employed, the different local hours of observation, and the divergent methods of reduction, it is no wonder that the small solar variations have been swallowed up in the bad workmanship of meteorologists. The prevailing methods have been sufficient for forecasting and for climatological purposes, but they are entirely inadequate for the cosmical problems whose solution will form the basis of scientific long-range forecasts over large areas of the earth, that is, for forecasting the seasonal changes of the weather from year to year. It is perfectly evident that if secular variations of any kind, such as the annual changes in terrestrial pressure, temperature, or magnetic field, are to be attributed to solar action, the original observations must be finally reduced to a homogeneous system. The local peculiarities of each station must be carefully eliminated, and the data of numerous stations must be concentrated before anything like quantitative cosmical residuals can be obtained. When we consider that there have been numerous changes in the elevations of barometers, various methods of reducing the readings, and many groups of selected hours of observations entering into the series at the same station, how could it be expected that any thing better than negative results in solar problems would be obtained? The skeptical attitude of conservative students, who declare that the many indecisive results already obtained mean that there is no true and causal solar-terrestrial synchronism, is, of course, quite fallacious until it has been demonstrated by the use of first-class homogeneous data that the suspected physical connection is imaginary. There is but little question that the existing uncertainty is in fact based upon the use of the very imperfect methods of observation and reduction which have prevailed in meteorological offices, rather than upon the unreality of the phenomena in nature. At present the difficulties of the research are diminishing by reason of two improvements; (1) a better knowledge of where to make the comparison, and (2) the gradual acquisition of reliable secular data. Thus, the prominence data are superseding the sun-spot numbers, and it has now become comparatively easy to traverse the magnetic and the meteorological fields with our improved standard curve of comparison, and to bring out the fundamental typical synchronism in nearly every series of observations, so far as the annual means are concerned.

The importance of emancipating this subject from the prevailing skepticism is evidently in the interests of advancing cosmical science. If we can prove that other forces than the Newtonian gravitation and radiation are interacting between the sun and the earth, it becomes a conclusion of vital interest to astronomers. As an example of the present state of opinion, we note Prof. Simon Newcomb's address[17] before the Astronomical and Astrophysical Society of America on December 29, 1902, in which he says:

> The conclusion is that spots on the sun and magnetic storms are due to the same cause. This cause can not be any change in the ordinary radiation of the sun, because the best records of the temperature show that, to whatever variations the sun's radiation may be subjected, they do not change in the period of the sun spots.

We shall, on the other hand, show in this paper that terrestrial temperatures do, as a whole, change with the variations of the solar prominences, and this will tend to modify Professor Newcomb's inference. The question whether the connection is direct or indirect, by a magnetic field or by some special action of radiation, is to be decided finally by an appeal to the observations. Dr. J. Hann writes in his Lehrbuch der Meteorologie, pages 626, 627:

> These can lead to the discovery of the period, but it is very difficult to find the true length of the period, since the amplitude of the variation of the meteorological elements within the period is not very great, because so many other influences are present, which stand in the way of deriving more accurate mean values out of long intervals of time. As yet no one has succeeded in surely deducing for any one meteorological element a cyclic variation of considerable amplitude.

These efforts have been applied to variations of temperature, clouds, rainfall, thunderstorms, hail, barometric pressures, cyclones, and winds, especially with the view of finding an 11-year period synchronous with that of the sun spots. It should be noted that a shorter period, of about three years, is probably the better period of synchronism to be studied. Also, synchronous movements need not be truly periodic. Indeed, there may be true correspondence with very irregular and aperiodic changes. It is easier to connect loosely constructed variations in the prominences of about three or four years duration with terrestrial variations than to establish synchronism in the 11-year sun-spot period. Dr. A. Sprung, in his Lehrbuch der Meteorologie, pages 366, 367, writes:

> Therefore, a connection between the sun-spot frequency and the changes in our atmosphere can not well be denied. It is probable that the periodic changes in the atmosphere are not caused directly through the sun spots, but that both phenomena are brought about through one common or by several interacting causes, whereby a displacement of the periods relative to one another becomes possible.

Prof. Cleveland Abbe has frequently expressed in the MONTHLY WEATHER REVIEW a very doubtful view regarding the advisability of such researches, with the object of discouraging further efforts to unravel the solar-terrestrial net. Thus, in the MONTHLY WEATHER REVIEW for June, 1901, page 264, he writes:

> As the periodicities in sun spots, the width of the spectrum lines, the magnetic and auroral phenomena are sufficiently well marked to be satisfactorily demonstrable, while corresponding variations in pressure, temperature, wind, and rainfall are small, elusive, and debatable, we must caution our readers against being carried away by optimistic promises. It is certainly impressive to the thoughtful mind to realize that there is even a slight connection between solar and terrestrial phenomena, but the delicacy of this connection is such that it still remains true that the study of meteorology is essentially the study of the earth's atmosphere as acted upon by a *constant source of heat* from the sun. None of these astrophysical studies should tempt the meteorologist to wander far from the study of the dynamics of the earth's atmosphere and the effects of the oceans and continents that diversify the earth's surface.

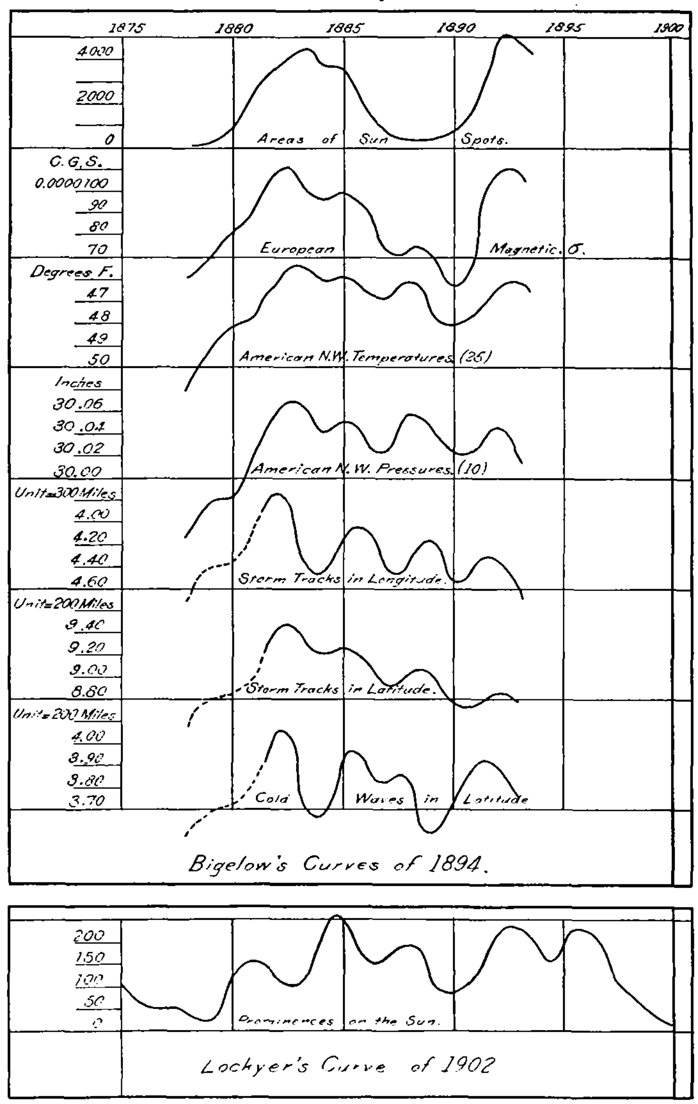

FIG. 5.—Solar and terrestrial synchronism.

We have, nevertheless, merely to recall the works of many scientists in order to realize how strong a hold this problem has upon the astrophysical meteorologist: Herschel, 1800; Gautier, 1844; Fritsch, 1854; Arago, 1855; Zimmermann, 1856; Wolf, 1859; Meldrum, 1870; Koeppen, 1873; Hill, 1880;

[17] Science, January 23, 1903.

van Bebber, 1882; Blanford, 1889; Bruckner, 1890; Lockyer, 1898; Carrington, Spoerer, Wolfer, and many others. The number of students who are taking up the problems of cosmical meteorology is rapidly increasing, and this shows that there is encouragement for such work.

The present paper continues the discussion of an investigation first published in 1894,[18] which brought out the fact that there is a synchronous variation in short cycles of about three years duration superposed upon the 11-year sun-spot period. In Bulletin No. 21, Solar and Terrestrial Magnetism, page 127, it was said:

> A comparison of the mean American meteorological curve with the European magnetic curve certainly shows conformity to such an extent as to exclude merely accidental physical relations. Should such a result be obtained also in the future, it will be a demonstration of the synchronism of the two systems of forces under consideration.

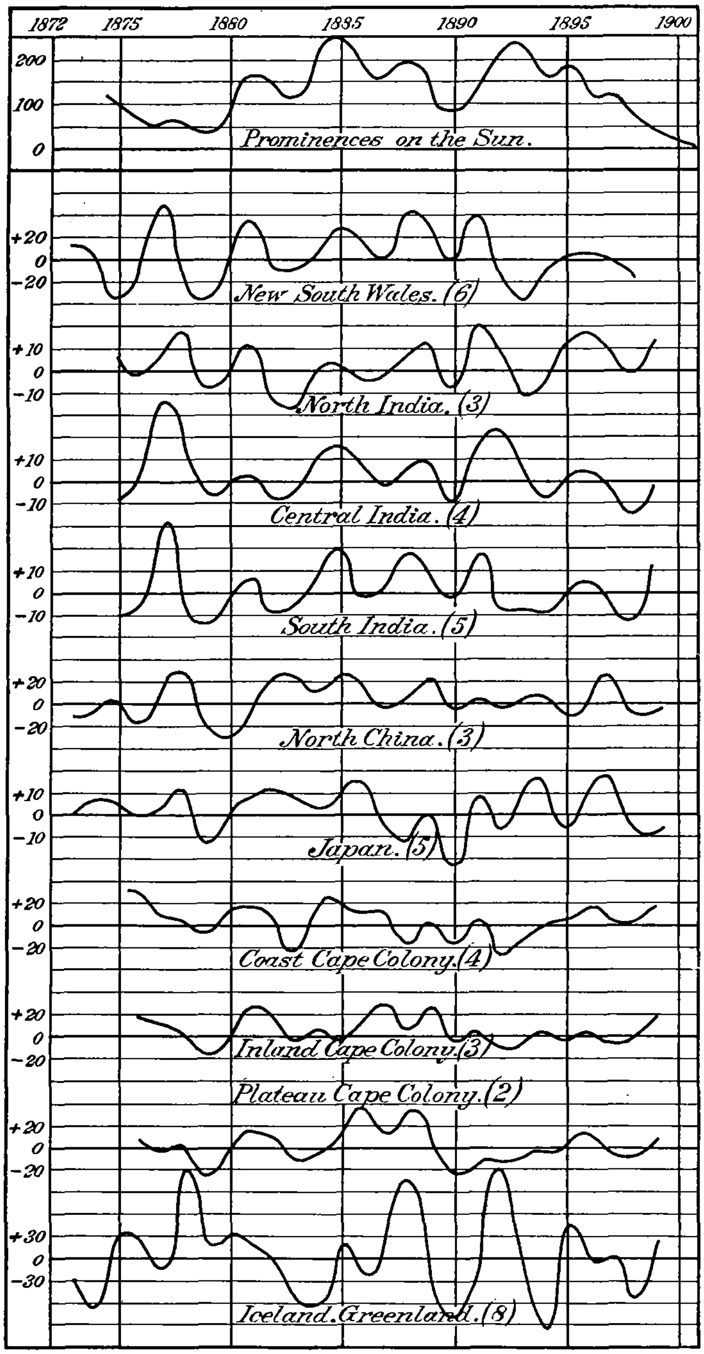

FIG. 6.—Variations of the annual pressure in the direct type.

[18] Inversion of Temperature in the 26.68-day Solar Magnetic Period. Amer. Journal of Science. Vol. XLVIII. December, 1894.

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Since that time advances have been made as follows:

The magnetic curve has been extended from 1841 to 1900; the barometric pressures of the United States have been reduced to a homogeneous system; the curves of prominence frequency on the sun have been computed by Lockyer and independently by myself; the variations of the prominences have been closely associated with the changes in the angular velocity of the solar surface rotations in different zones, especially in the polar latitudes; the type of internal circulation necessary to produce this polar retardation, and to transform the solar mass into a polarized magnetic sphere, has been indicated.

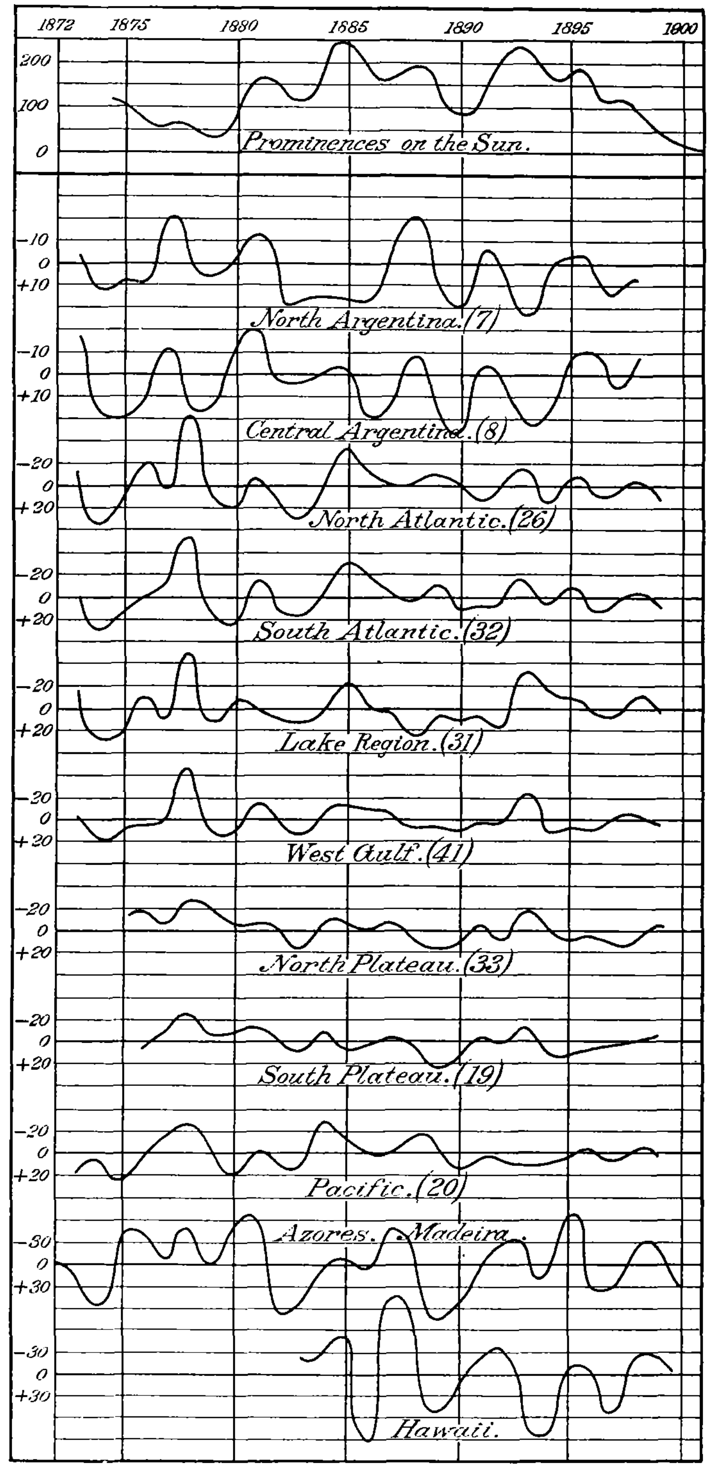

FIG. 7.—Variations of the annual pressure in the inverse type.

In the present paper we shall show the results of a discussion of the annual residuals of pressure and temperature in all parts of the earth. These have a variation in *direct* synchronism with the prominences, in certain parts of the earth, but under special conditions of orography the synchronism is of the *inverse* type. This chain of evidence is strong enough to induce confidence in regard to the fact that this solar-terrestrial physical synchronism really exists.

THE UNSATISFACTORY STATE OF THE OBSERVATIONAL DATA.

The two prevailing difficulties in extracting suitable data from the published reports of meteorological observatories, and reducing them to a homogeneous system, are the numerous changes in the elevation of the barometers, and in the very different hours of making the observations. Without the expenditure of labor entirely beyond the capacity of a single office to bestow upon the task, when the research for synchronism is extended to the entire earth, it has been necessary to use some simple devices for the sake of arriving at approximately homogeneous residuals. The work for the United States is complete for the pressures, and is in progress for the temperatures. By inspecting my Barometry Report[19] it is easy to see the reason for the necessity of the reduction. In order to give some idea of the state of the data in other countries, we note the following with respect to the barometric pressures:

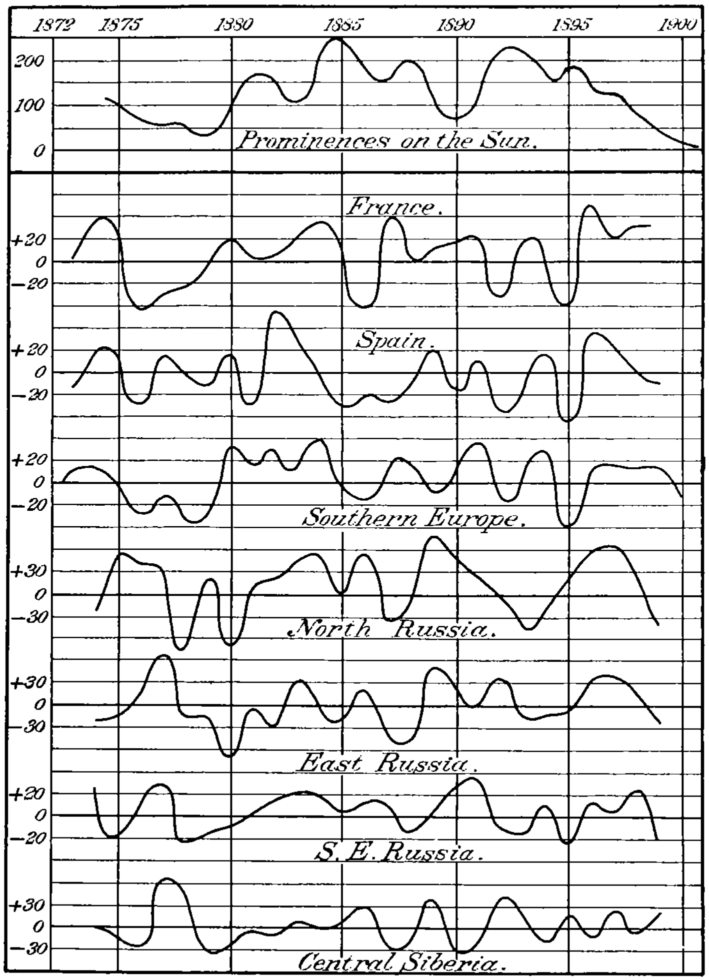

FIG. 8.—Variations of the annual pressure in the indifferent type.

For Russia-Siberia, several stations changed elevation more than once.

India, there are numerous changes of elevation.

South Africa, numerous changes of elevation, and also of the hours of observation.

New South Wales, the monthly means of observations alone were published. These had to be collected before the annual means could be computed.

Argentina, the monthly means of observations alone were published, and these also had to be collected before the annual means could be computed. The stations have quite short records.

Iceland and Greenland, very few changes in elevation, but not long records.

In general all the annual pressure curves were plotted, and a mean pressure and normal gradient were determined, from which the amplitude variations were taken off as residuals. Since our purpose was simply to secure the most probable annual residuals this graphic method was substituted for the exact computations which ought to be made. Frequently the secular gradient slope was so prominent throughout the series for a single station as to suggest a gradual change in the correction of the barometer relative to a normal standard.

With respect to the temperatures, the annual means were extracted from the reports, and the mean values for the several series were computed, so far as they were apparently homogeneous, and from these the residuals were formed. As the cosmical annual variation of temperature is only 1° to 2° F., it was often possible to break up a long series at the same station into homogeneous sections; but this was done cautiously, and only after clear evidence of a discontinuity in the local conditions. The great difficulty with the temperature data consists in the numerous hours of observation that have been adopted, or in the numerous selected groups of hours from which the means were derived. Many of these differences arose from artificial attempts to obtain an approximately correct 24-hour mean, to which in fact all meteorological data should be very carefully reduced. Some of the combinations of hours used are as follows:

United States, Washington mean time, 7:35, 4:35, 11:35; 7:35, 4:35, 11:00; 7, 3, 11. Seventy-fifth meridian time, 7, 3, 11; 7, 3, 10; 8, 8; maximum, minimum.

New South Wales, 9 a. m.; 9, 3, 9; maximum, minimum.

South Australia, 9, 3, 9; 9, 12, 3, 6, 9; maximum, minimum.

West Australia, 9, 3; 9, 12, 3; 9 a. m.; 6, 6; maximum, minimum.

Ocean Islands, hourly; 9, 3, 9, minimum; 6, 9, 1, 3, 3:58.

Japan, 9:30, 3:30, 9:30; 4-hourly, or 2, 6, 10, 2, 6, 10.

China, hourly; 10, 4, 10.

India, 8, 10, 4; 10, 4; 6-hourly, or 10, 4, 10, 4; 9:30, 3:30; 9, 4; 10:30, 3:30; maximum, minimum.

Russia-Siberia, 7, 1, 9; 7, 2, 9; 9, 12, 9; 8, 1, 9; hourly.

Europe, 7, 2, 9, 9; 7:45, 8; 6, 2, 10; 3-hourly; maximum, minimum; 7, 10, 1; 4, 7, 11; 7, 1, 7; 6, 9, 12; 3, 6, 9; 6, 12, 9; hourly.

Azores-Madeira, 9, 3, 9.

North Africa, 7, 2, 9; 7, 11, 2, 5; 7, 1, 6; 9, 3, 9.

South Africa, 6, 12, 6; 6, 2; 9, 9; 8, 8; 8 a. m.

South America, 7, 2, 9; hourly.

Iceland-Greenland, 8, 2, 9.

From such an exhibit it is no wonder that meteorology has not yet contributed its proper share to accurate cosmical physics. It is needless to recount the reason for this state of affairs, but only to urge as speedy a remedy as is possible. It might be argued that no results can be derived from such data; but this is not true, as a study of the residuals summarized in this paper amply confirms. It is, perhaps, surprising that valuable results can be extracted from the data, and this only proves how important such work might be made if sufficient care were exercised in selecting the hours of observation, and establishing rigorous methods of reduction. It frequently happens that at a given station the same hours continue to be used for many years, so that in effect its own residuals are nearly homogeneous. The means of the various combinations of selected hours generally approximate a true 24-hour mean, so that on the whole there is something like homogeneity in the differ-

[19] Report of the Chief of the Weather Bureau, 1900-1901, Vol. II.

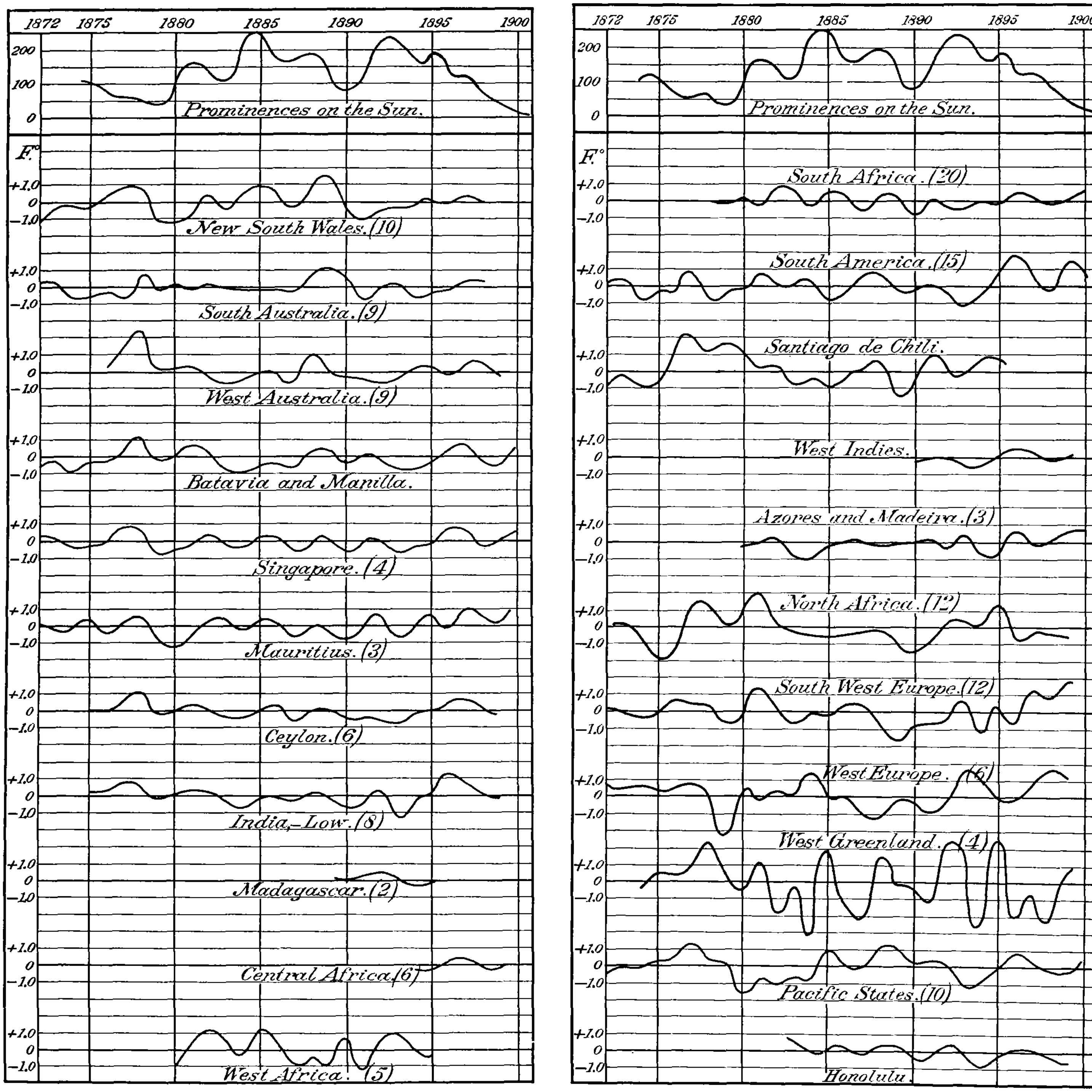

FIG. 9.—Variations of the annual temperature in the direct type.

ent changes. The fact that residuals synchronous with solar variations actually survive, is a satisfactory evidence that the causes producing them are solar and not local terrestrial.

It is not possible to print in the MONTHLY WEATHER REVIEW the table of residuals for each station, and we must confine ourselves to the curves representing the mean residuals for a group of stations, the number being entered in connection with the name of the country. Thus, for New South Wales the pressure curve, fig. 6, was determined from six stations, Albany, Bathurst, Deniliquin, Goulborn, Newcastle, Sydney.

RESULTS OF THE OBSERVATIONS.

The argument for solar and terrestrial synchronism may be recapitulated as follows:

Bigelow's curves for 1894 showed a synchronism in a short period of about three years, superposed upon the 11-year sunspot curve, for the following elements: Terrestrial magnetic field, American temperatures, pressures, storm tracks in longitude and latitude, and cold waves in latitude. In 1902 Lockyer worked out the annual variation in the solar prominences and arrived at the same system of minor crests in the sun that had previously been determined at the earth. These curves are shown on fig. 5, "Solar and terrestrial synchronism."

A study of the temperature and the pressure residuals for the entire earth shows that the phenomena of inversion prevails in the earth's atmosphere, localizing the effect of solar action in two typical curves which are the inverse of one another. I have previously found a form of inversion of energy in the terrestrial magnetic field, and efforts have been made to explain the phenomenon. Besides the secular inversion here illustrated, I have found a semiannual inversion in the meteorological elements of the United States, as stated in other places, and much work has been done in developing this important fact.

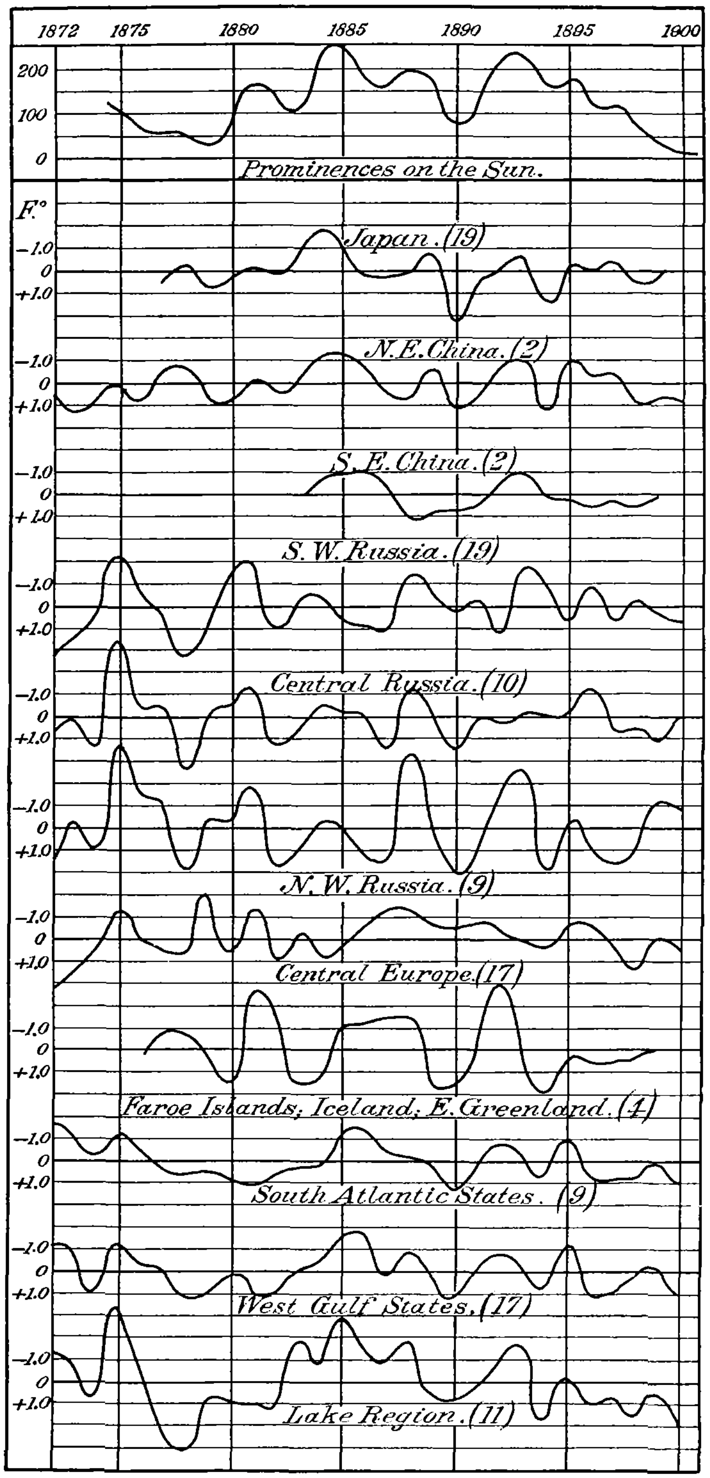

FIG. 10.—Variations of the annual temperature in the inverse type.

We have treated the secular inversion as follows: The curves of the mean residuals of the pressures and temperatures, taken by geographical groups as indicated, were plotted to scale and compared with the Lockyer solar prominence curve as to the recurrence of the successive maxima and minima. They were then associated in three groups, as follows:

I. Direct type, wherein the solar and the terrestrial maxima closely match each other throughout the interval 1873–1900.

II. Inverse type, wherein the terrestrial curves must be inverted to make the maxima coincide.

III. Indifferent type, wherein there is not sufficient evidence of conformity with the type curve to be satisfactory.

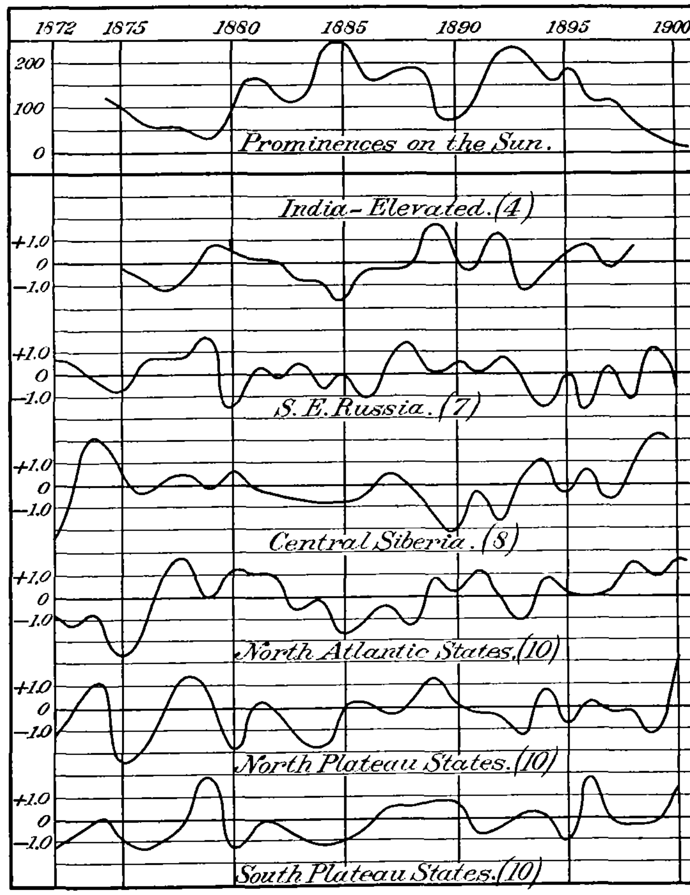

FIG. 11.—Variations of the annual temperature in the indifferent type.

There may be differences of opinion as to the assignment of some of these curves, but the reader can make any different arrangement that he prefers. It seems to me that the general fact of synchronism is so pronounced as to call for the careful consideration of meteorologists. Fig. 6, "Variations of the annual pressure in the direct type;" fig. 7, in the "inverse type;" fig. 8, "indifferent type;" fig. 9, "Variations of the annual temperature in the direct type;" fig. 10, in the "inverse type;" and fig. 11, in the "indifferent type," are sufficiently explicit without further explanation. The unit for the pressure variation is 0.001 inch, and that for the temperature is 1.0° F. The average range in annual pressure amplitude amounts to as much as 0.060 inch and that for the temperature to 2° or 3° F, more or less.

DISCUSSION OF THE LOCAL INVERSIONS.

These suggestive curves deserve more discussion than is possible in this connection, but fuller data and further remarks will be found in a forthcoming report, which will contain the original data in full. It may be desirable to call attention to the geographical distribution of the types of synchronism thus indicated, by plotting on world charts *D*, *I*, and *#*, respectively, for the direct, inverse, and indifferent types. Fig. 12, "Distribution of the pressure types," shows that, taking the earth broadly, the region around the Indian Ocean gives direct synchronism, South America and North America give inverse synchronism, while Europe and Siberia give an indifferent type. Greenland and Iceland seem to have direct type

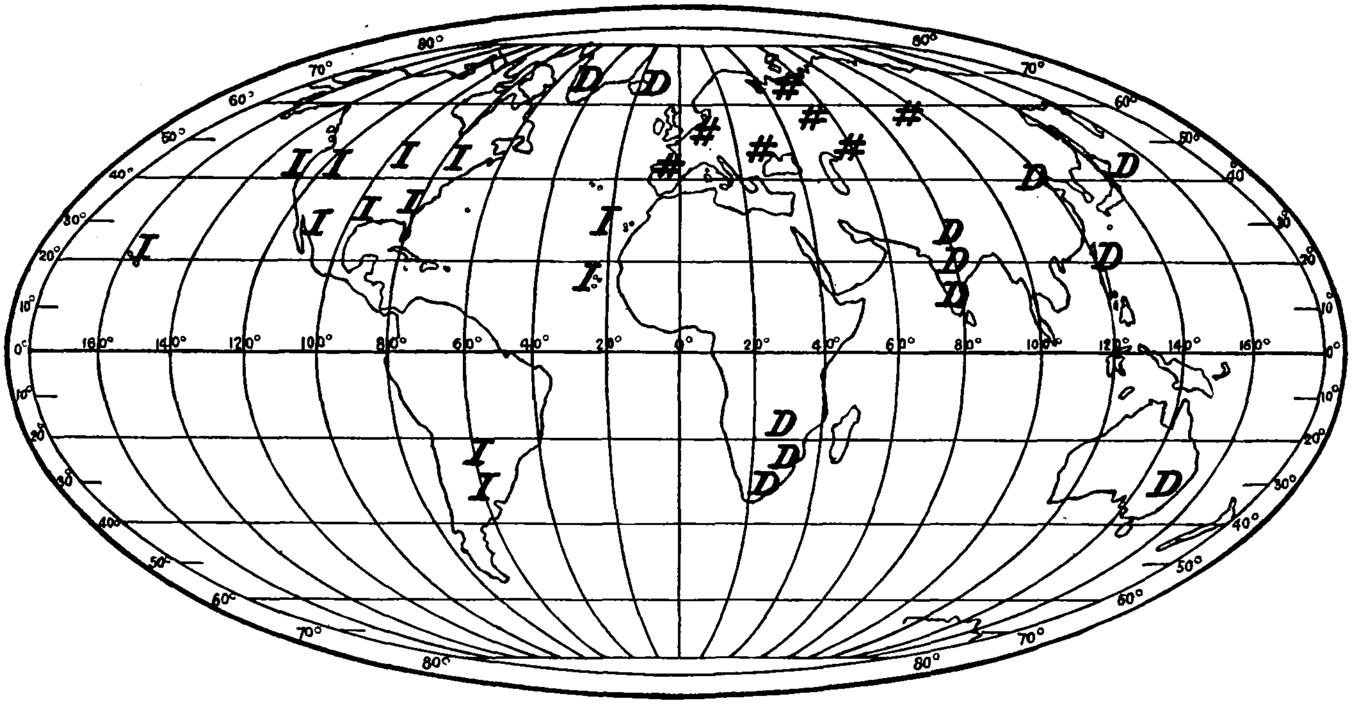

FIG. 12.—Distribution of the pressure types.

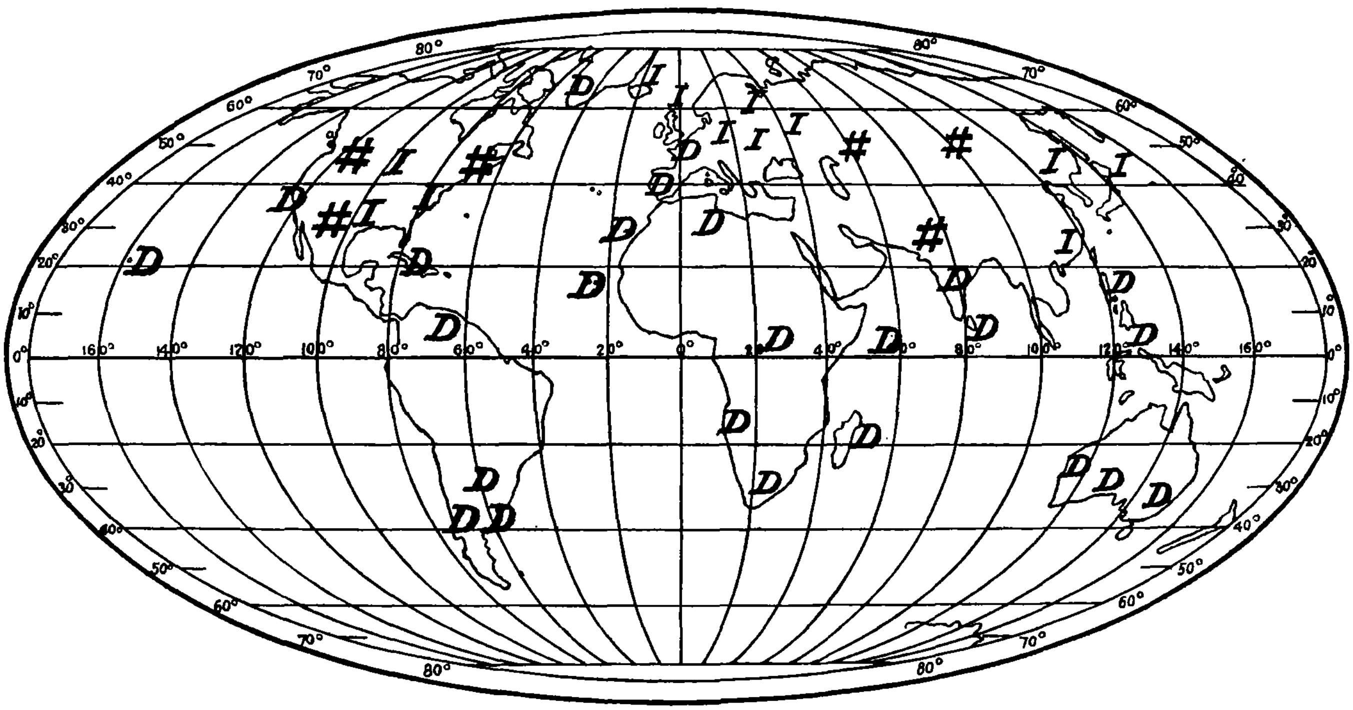

FIG. 13.—Distribution of the temperature types.

like the Indian Ocean. Fig. 13, "Distribution of the temperature types," shows that there is synchronism of the direct type for the Indian Ocean, Africa, South America, the West Indies, and the Pacific islands generally—that is to say, throughout the Tropical Zone. The inverse or the indifferent types prevail in Asia, Europe, and North America generally—that is, throughout the North Temperate Zone.

Taking the earth as a whole, the temperatures synchronize directly with the solar energy in the Tropical Zone, and inversely in the temperate zones. The indifferent type prevails in the plateau districts of the continental areas, probably because the solar type is there so broken up by the local climatic conditions as to practically obscure the synchronism. In the pressures the Eastern Hemisphere tends to direct synchronism, except in Europe and Russia, where the indifferent type prevails, and the Western Hemisphere to the inverse type. It may not be practicable to explain all that this means, but apparently we are dealing with the complication caused by superposing an atmosphere in circulation upon the unequally heated surface of the earth. The surging of the atmosphere as a whole from one hemisphere to the other, or from the continents to the oceans, is concerned in producing these effects. The trend of the great mountain systems strongly differentiates the circulation of the lower strata. Thus, the Himalaya Mountains, running east and west, check the flow of air from the Tropics to the Asiatic Continent, while the Rocky Mountains and the

Andes system favor the flow along the meridians, especially in the United States. As a result, the number of cyclones crossing the United States is many times the number crossing Siberia, which is in fact singularly deficient in cyclones. South America shows a similar defect in circulation, because it lies too near the Tropical Zone.

The United States is covered by an active circulation between the Tropics and the north Polar regions, Siberia by a stagnant atmosphere, and Europe generally by a mixed and indifferent circulation, since the American cyclones tend to break up upon the territory of Europe after crossing the Atlantic Ocean. Hence, the region about the Indian Ocean is favorable for detecting direct synchronisms of pressure and temperature with the solar prominences by reason of its quiescent atmosphere, and the United States is well placed to respond to an inverse synchronism, by reason of its active circulation with a pronounced component from the north Polar regions. Europe does not possess an atmosphere which registers the solar and terrestial synchronism in a very efficient manner. This may account for the fact that the European attempts to establish a definite synchronism have issued generally with negative results. As has already been suggested, too much emphasis has been put upon the failures to make out the connection between the solar and the terrestrial synchronisms.

It should be noted that C. Nordmann[20] and A. Angot[21] deduced for certain tropical stations small residuals of temperature which are *inverse* to the sun-spot curve, but apparently synchronous. These authors have smoothed their curves by grouping successive years, and have reached small residuals. Since the synchronism should display the annual variations intact, as given above, it may be questioned whether any process for eliminating the minor deflections from year to year is desirable.

We also note the important fact that the wide amplitudes which are characteristic of the 11-year sun-spot curve, and which it has been chiefly sought to discover in the meteorological elements, does not, according to this research, appear at all prominently in the residuals. It is only the short period of about three years that displays the solar terrestrial synchronism. I am not, at present, able to indicate what this result implies in solar physics, but it certainly carries with it a change in our method of approaching the entire problem.

[20] The periodicity of sun spots and the variations of the mean annual temperatures of the atmosphere. M. Charles Nordmann. Comptes Rendus. Paris, June, 1903. Translation in Monthly Weather Review, August, 1903. P. 371.

[21] The simultaneous variations of sun spots and of terrestrial atmospheric temperatures. Prof. Alfred Angot. Annuaire de la Société Météorologique de France, June, 1903. Translation in Monthly Weather Review, August, 1903. P. 371.

THE PROBLEM OF THE CYCLONE.

By F. J. B. CORDEIRO, dated Newport, R. I., September 5, 1902.[1]

It was Lord Kelvin who showed that a mass of fluid in vortex motion acquires all the properties of a solid, the chief of which are rigidity and elasticity. It was on this demonstration that he founded his astonishing vortex theory of matter. He showed perfectly that an atom of matter might possibly be nothing else than the frictionless fluid ether in a vortex state. A vortex in the ether would thus possess rigidity, elasticity, inertia, and all other properties of matter. In the same way a vortex in the atmosphere acquires shape and preserves it like any solid, as well as rigidity and elasticity. Professor Tait's smoke rings, which suggested to Lord Kelvin his ethereal vortex atoms, have all the properties of solid bodies. So, when I treat a revolving mass of air as being dynamically the same as a solid I do what Lord Kelvin has shown is perfectly admissible.[2]

Poisson's general equations for rotary motion of a solid having one fixed point O are given in most works on mechanics and read as follows:

$$
(1)\qquad
\begin{aligned}
C\frac{dw}{dt} + u\cdot v\cdot(B-A) &= L,\\
B\frac{dv}{dt} + u\cdot w\cdot(A-C) &= M,\\
A\frac{du}{dt} + v\cdot w\cdot(C-B) &= N.
\end{aligned}
$$

In these equations u, v, and w are the angular velocities of rotation of a solid body with reference to the three coordinate axes, X, Y, and Z, fixed in space and intersecting at the fixed point O. A, B, and C are the moments of inertia of the solid mass with reference to its own three principal axes, the latter being in motion relative to the three fixed axes. L, M, and N are the moments of the accelerating forces that act upon the body from without taken with reference to the three principal axes.

If we apply these equations to a symmetrical solid of revolution, such as a ring, or an ellipsoid of revolution having its fixed point in its axis of figure, then we obtain the equations for the movement of a gyroscope or rotascope, or a top, and we are able to explain all the motions of those bodies with reference to the support on which they stand. If, however, instead of supposing the revolving body to have a fixed point, we give the latter also a definite motion, as, for instance, when the gyroscope, with its support, is carried with the earth around the earth's axis in its diurnal rotation, we can then deduce the movement of the gyroscope with reference to the meridian of the locality.

If the disk of the gyroscope be supposed to be horizontal, or nearly so, and revolving rapidly about an axis that is vertical, or nearly so, and if its axis is not constrained, but free to move on the earth's surface, we have a case apparently analogous to the movement of a cyclone or hurricane, at least in so far as the latter consists of a mass of air rotating in a horizontal plane. Practically the air within a cyclone is known to be either ascending or descending and changing continually, so that energy is brought into it from without and carried outward from it. If the energies thus added and lost counterbalance each other, we may perhaps hope to deduce from the laws of the gyroscopic motion of a solid some insight into the laws of the motion of the hurricane along the earth's surface.

The above general equations of rotation were in 1858 put into a convenient form for the study of the gyroscope by Major, afterwards General, J. G. Barnard, of the Army Engineers, and his paper is reprinted as No. 90 of Van Nostrand's Science Series.[3] In Major Barnard's little volume the reader will find deduced from fundamental principles the law of gyroscopic motion, which is this: If a spinning gyroscope or a spinning wheel be turned about an axis perpendicular to its own axis of rotation, a deflective force will be developed per-

[1] The Editor has retained this paper for a year in hopes that the author would elaborate the mathematical deduction of the formulæ that he uses, but the latter has thought best to simply add a few references to the article by Major Barnard. The reader will find the phenomenon of the gyroscope treated in many modern works on mechanics. The fact that Mr. Cordeiro rests his theory entirely on the assumption that we may deal with the cyclone as if it were a rotating solid deprives his paper of any special interest to the student of hydrodynamics, but his results will, it is hoped, lead others to a more rigorous treatment of the subject.—ED.

[2] The vortex ring of Helmholz and Kelvin constitutes a different sort of motion from that within a cyclone and still more different from that of a simple gyrating mass moving like the particles of a spinning gyroscope. It is, therefore, quite hazardous to assume that the latter will show the mechanical peculiarities of the cyclone. The vortex theory of atoms has been abandoned.—ED.

[3] Analysis of Rotary Motion as Applied to the Gyroscope. By Major J. G. Barnard. D. Van Nostrand, publisher, New York, 1887.